AIR SERVICE INFORMATION CIRCULAR

(AVIATION)

PUBLISHED BY THE CHIEF OF AIR SERVICE, WASHINGTON, D. C.

Vol. IV | July 15, 1922 | No. 357

REPORT ON TEST OF BIJUR IGNITION END STARTER FOR AIRPLANE ENGINES

(EQUIPMENT SECTION REPORT)

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March 25, 1922

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

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TEST OF BIJUR IGNITION END STARTER FOR AIRPLANE ENGINES.

OBJECT.

The object of this test was to determine the characteristics and performance of the Bijur rear end starter.

DATE AND PLACE.

The tests were conducted by the Electrical Branch, Equipment Section, McCook Field, Dayton, Ohio, over a period of about nine months, ending August, 1921.

DESCRIPTION AND DIMENSIONS.

Figures 5, 6, and 7, respectively, show views of an assembled starter.

Figure 1 gives the outline dimensions.

Table 4 gives the weights of a starter and accessories.

Figure 16 shows the starter as installed on a Liberty "12" airplane engine.

Figure 10 is a view of the motor and reduction gear housing.

Figures 8 and 9 show the assembly of the back-fire release mechanism and main bearing.

Figures 11 and 14 show disassembled view of the back-fire release mechanism.

Figure 12 shows disassembled view of planetary reduction gearing.

In the following explanation of the action of the starter, the cross section view (see Fig. 2) can be used to advantage.

As soon as the series starting motor is energized, the bevel pinion, shown in position in Figure 10, begins to revolve. This pinion meshing with the bevel gear, shown in Figure 12, causes the planetary gear system to revolve, at a reduction of 4.5 to 1. The idler gears, shown in position in the planetary gear assembly, Figure 12, and disassembled in part 4 of Figure 14, being in mesh with the fixed internal gear, part 8, Figure 14, and the free internal gear, part 8, Figure 14, cause the free internal gear, Figure 14, to revolve, at a reduction of 23.1. The total gear reduction from motor bevel pinion to the driving barrel is 103.5 to 1. The free internal gear being integral with the driving barrel, part 2 of Figure 14 causes the entire back-fire release mechanism, as shown in Figure 8, to revolve.

The friction disks, parts 6 and 9 of Figure 14, shown in position in Figures 7 and 9 tend to keep the spline screw, part 3, Figure 11, from revolving. The spline nut, part 1, Figure 11, being in mesh with the thread of the spline screw tends to revolve the spline screw. As a resultant, the spline screw is forced out of the spline nut and assumes a position with respect to the starter, as shown in Figure 5. With the spline screw in this emerged position, it is in mesh with the spline on the crank shaft of the engine being started. The spline screw is kept from emerging further because of a nut, part 7 of Figure 11, which bears against a shoulder in the driving barrel, part 2 of Figure 14. The compression washers, part 5 of Figure 11, being between the inside shoulder of the driving barrel, part 2 of Figure 14, and the radially projecting lugs on the spline nut, prevent the spline nut from advancing along the spline screw toward the threaded end of the spline screw. However, if the spline screw should be held stationary, by virtue of an extremely stiff engine, the spline nut would advance along the spline screw, compressing the compression washers. A point would be reached where the projecting lugs of the spline nut would draw out of the spline plate, part 1 of Figure 14, and thereby allow the driving barrel to rotate in its normal direction. As the next spline in the spline plate comes along, the compression washers tend to force the spline nut into its normal position. This it does with a click because of clearance between splines and also because of the release of torsion on shaft.

If the starter circuit is not interrupted, the clicking continues at regular intervals. The starter should be interrupted as soon as the first click is heard. A continued operation of this, the back-fire release, wears the edges off the spline plate and spline nut projections, causing the back-fire release mechanism to operate at a lower torque. The manner in which the projections are worn away can be easily seen in part 1, Figure 14, the upper portions of the projections having been rounded off under the action.

The back-fire release mechanism is designed to function at about 600 pounds feet torque. This torque is more than sufficient to turn over a cold Liberty "12" engine.

In starting, if the engine should back-fire, the back-fire release mechanism will operate, thus protecting both starter and engine.

PROCEDURE.

The following tests were made on a sample Bijur ignition end starter:

1. Operation at no load.
2. Characteristics under various loads.
3. Performance when subjected to back-fires.

For operation at no load a 12-volt storage battery was connected across the starter motor terminals, through a suitable switch. The amperes input, voltage and spline screw revolutions were noted. Data are recorded in Table 1.

The operation of the spline screw was observed. Before the starter switch was closed the spline was forced back into the spline nut. The switch was then closed and the action of the spline screw observed. The action was immediate and continuous, the spline screw emerging with no apparent delay.

The starter was then attached to a Prony brake, so that the output at the spline screw could be measured, by

means of an arm and a scale. The loading was increased by increasing the friction between the brake band and the brake. Figure 3 shows the Prony brake and manner of attaching the starter.

The power supply consisted of four 12-volt, 60-ampere hour storage batteries connected in multiple.

The test consisted of loading the starter in successive steps. For each loading armature amperes, volts across the motor terminals, revolutions of brake drum, and the weight at torque arm were recorded.

Data are recorded in Table 2. Sketch of connections are shown in Figure 3.

Characteristic curves of the performance are shown in Figure 4.

The starter was then mounted on a Liberty "12" engine. The source of power was one 12-volt, 60-ampere hour storage battery. The spark of the engine was so manipulated that while the engine was being turned over by the starter, the engine would back-fire. Such back-fire would cause the back-fire release mechanism to operate. As the engine back-fired, the torque exerted by the starting motor was sufficient to cause the engine to stall. At no time did the back-fire cause the back-fire release mechanism to release past more than one spline. The starter was subjected to 10 distinct back-fires.

After the back-fires, the starter was disassembled and an examination of the parts was made to determine the effect of the back-fires on the starter parts. The only effect noticeable was a wearing of the spline nut and spline plate splines, as shown in the photograph of the spline plate in Part 1 of Figure 14.

TABULATION OF DATA AND RESULTS.

Data of no load operation of starter are tabulated in Table 1.

Data of operation of starter under different loads are tabulated in Table 2.

Table 4 gives the weights of starter and accessories for a starter installation.

Data of performance of starter when subjected to back-fires are tabulated in Table 3.

DISCUSSION.

The first starter, used to any appreciable extent on Liberty "12" engines, was the Bijur propeller end starter. Although having the necessary power, it had several undesirable features.

1. The engagement was not positive. The engaging action depended on the speed of the motor and the inertia of the pinion shaft. This required a minimum of friction between the screw shaft and the spline nut. Any particles of dirt getting in on the bearing surface between the barrel drive and the pinion shaft, or in the screw of the screw shaft and spline nut, tended to cause the pinion shaft to turn with the barrel drive before it emerged far enough to mesh with the starting motor gear.

2. Due to location of starter, dirt particles sifted into all working parts and prevented the efficient operation of the starter.

3. The propeller end starter had no protection against back-fires or heavy overloads.

4. The location at the propeller end was a drawback for several reasons, namely:

(*a*) It required a special radiator.

(*b*) It could not be used with a supercharger.

(*c*) It required a longer length for connection to the battery.

(*d*) To change a propeller end starter necessitated the removal of the radiator each time.

Having the above points in view, the Bijur Motor Appliance Co. agreed to develop a starter for the Engineering Division which could be mounted on the ignition end of the Liberty "12" engine, and which would also include the following features:

1. A more positive engagement.
2. The chance for dust particles getting into the working parts reduced to a minimum.
3. A back-fire release, or overload protective device.
4. The ignition end location.

This enabled starters to be installed or changed easily and at the same time required a shorter length of cable for connection to the battery.

The Bijur Motor Appliance Co., accordingly, submitted several experimental models for test. The operating characteristics of these were very favorable and, with several recommended mechanical changes were considered as satisfactory for production. An engineering report (see Air Service Information Circular, Vol. I, No. 22) to this effect was made.

In March, 1920, a production order, No. 530037, was issued by the Procurement Section, Washington, D. C., for 590 Bijur ignition end starters.

Six starters built on Production Order No. 530037 were delivered to this division for acceptance tests on or about February 15, 1921. Five of these starters showed a premature functioning of the back-fire release as determined by attempts to turn over a cold Liberty "12" engine on the torque stand. When placed on a Prony brake for torque test, they all showed an average release point of about 360 pound-feet.

On back-fire, also a few while being tested on Prony brake showed a structural weakness in the driving barrel, as well as in the spline plate. These parts fractured under operation of the back-fire release mechanism.

A letter was written February 23, 1921, to the chief of Air Service, regarding the faults as brought out by these tests.

The Bijur Motor Appliance Co. went after the trouble and as a result made several changes that have enabled the starters to perform their function satisfactorily. They changed the pitch of the screw shaft and spline nut, which remedied the premature functioning of the back-fire release. The fractures of driving barrel were due to heat treatment, which has been eliminated.

About June 1, 1921, six starters with improved spline nut, screw shaft, and driving barrel were subjected to 10 back-fires each, after torque curves to stall had been taken on each one. Four of these, on back-fire, stalled the engine without releasing more than once or twice. On the fifth one, the back-fire release mechanism operated 10 times with 2 complete stalls. The sixth one jammed completely. Upon disassembly, the fifth one showed a worn edge on the spline plate, allowing the back-fire device to release a little earlier; otherwise it was satisfactory. The

sixth one jammed because of a broken idler stud causing a jamming of the idlers in the internal gearing. A sample of the broken spline plate, driving barrel, and the idler stud are shown in figure 15.

It is considered that the improved starters, as tested, are very satisfactory. It is reasonably felt that the breakage of spline plates and driving barrels has been reduced to a minimum, while the failure of the idler stud is considered a rare failure.

There is no question of the ability of the Bijur ignition end starter to turn over a Liberty "12" high compression airplane engine. Even in cold weather, the starter functioned and turned over the engine. The weather referred to is at Dayton, Ohio, and this winter (1921–22), the temperature has been between 5° F. and 10° F. several times.

The mounting of the starter is very simple. All that is required is to remove the rear crank-case cover plate and screw in 3/8-24 studs, 1¾ inches long in all but the top tapped hole, the starter flange being drilled to correspond, is slipped over the studs and the starter fastened in place. No lining up of the spline screw with the spline gear on the crank-shaft is necessary. All connections from the battery to the starter must be made with No. 00 stranded cable, double wrapped with varnished cambric (United States Spec. No. 27074), and covered with a double cotton braid. This size cable is necessary because of the high current taken by the starter motor (under load), and also to keep the voltage drop in the cables to a minimum.

The choice between a manually and a magnetically operated switch depends on the distance between the battery and the starter and should be made as short as is possible. A magnetically operated switch should be used whenever at least 3½ feet of No. 00 cable can be saved by so doing. If the starter circuit must pass near the pilot, the manually operated switch is more economical of weight, providing the switch can be installed where it can be readily reached by the pilot.

CONCLUSION.

The Bijur ignition end starter is well suited for use in airplanes to turn over a Liberty "12" engine at starting for the following reasons:

1. It is compact.
2. It is light in weight.
3. It has ample power.
4. It is very easily attached.
5. It eliminates danger to mechanic at starting.
6. Its use enables cross-country flights without danger of stalling at some out-of-way location, because of lack of manual help for starting. This is especially true of a forced landing in some out-of-the-way location.

TABLE 1.—*Bijur ignition end starter characteristic curves.*

Amperes.	Volts.	Watts input.	No load.		Watts output.	Per cent efficiency.
			Revolutions per minute.	Torque.		
70	11.8	827	87	.....	.....	.....

TABLE 2.—*Load characteristics.*

Amperes.	Volts.	Watts input.	No load.		Watts output.	Per cent efficiency.
			Revolutions. per minute.	Torque.		
164	11.2	1,836	49	52	357	19.4
200	10.85	2,263	40.3	108	510	26.9
229	10.7	2,450	37.3	140	731	29.8
261	10.5	2,740	33.4	188	884	32.2
286	10.35	2,960	31.0	224	975	32.9
322	10.18	3,280	28.3	272	1,080	32.9
335	10.10	3,385	27.3	288	1,104	32.6
403	9.77	3,940	23.7	372	1,236	31.3
459	9.50	4,360	21.2	436	1,298	29.8
513	9.22	4,730	18.8	500	1,320	27.9
574	8.87	5,090	16.5	572	1,324	26.0
632	8.5	5,370	14.0	644	1,262	23.5
890	6.8	5,990	0	860	.....	.....

TABLE 3.—*Results of back-fires on starter.*

Engine stalled eight times.
Back-fire release operated three times.
Result.—Splines of spline plate and spline nut worn a little.

TABLE 4.—*Weight of starter installation.*

	Pounds.
Bijur ignition end starter	30.80
Four feet No. 00 flexible copper cable	2.18
Manually operated switch	1.20
Cable terminals (minimum of four needed)	.252
Total	34.432
Magnetically operated switch	2.70
Push button for magnetic switch	.28
Push button wire (20 feet)	.276
Weight of magnetic switch accessories	3.236

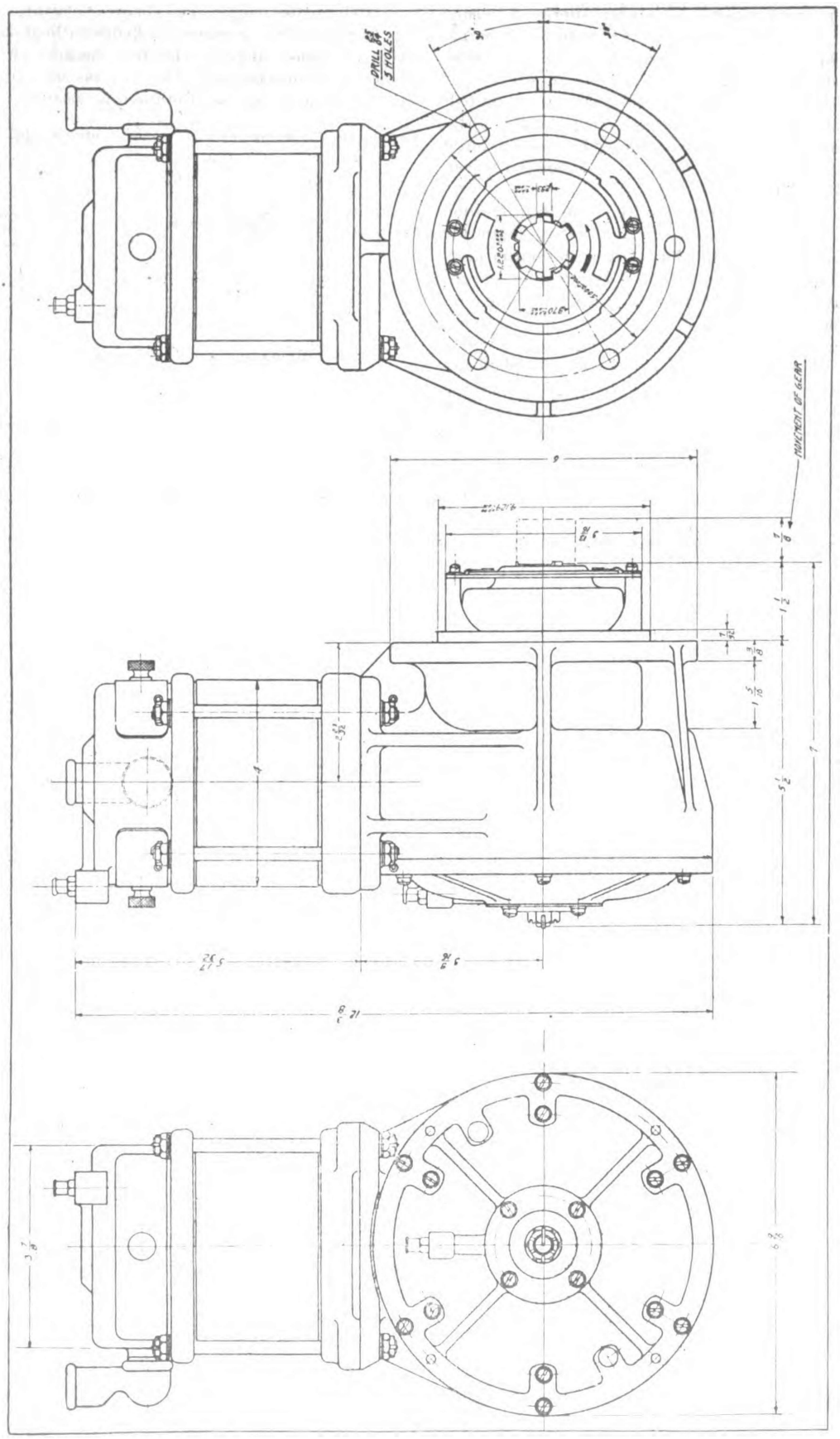

FIG. 1.—Rear end starter for Liberty "12."

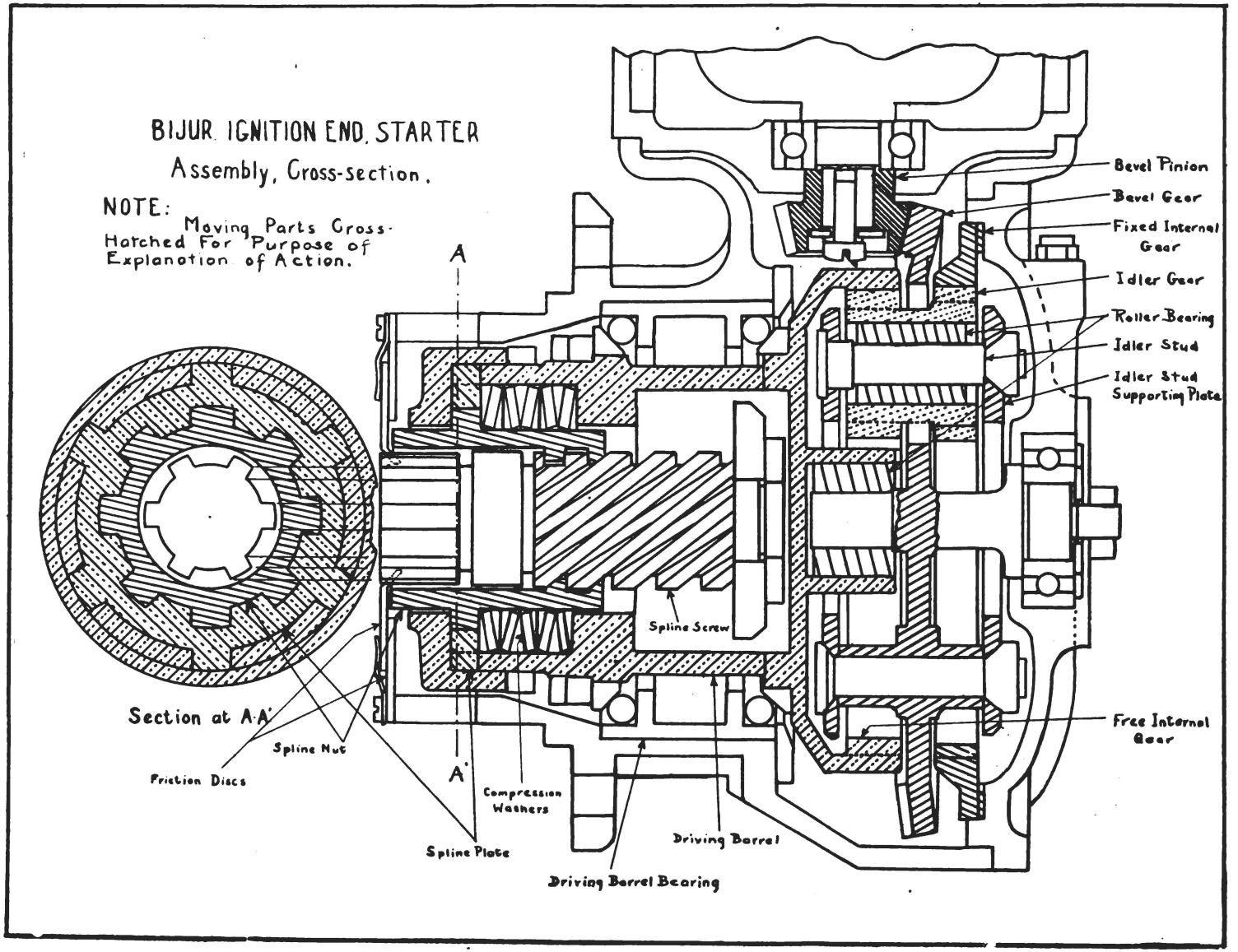

FIG 2.

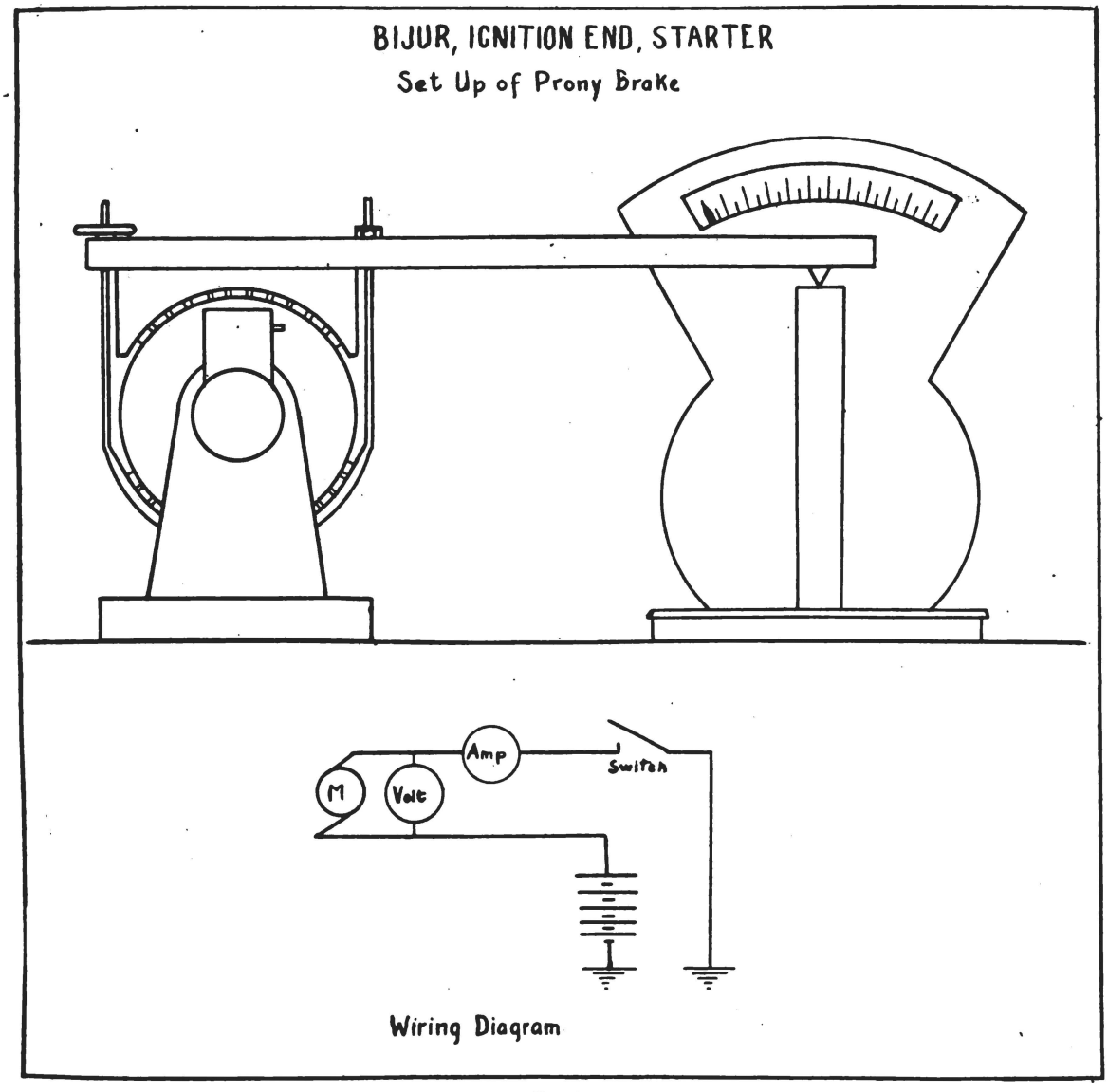

FIG. 3.

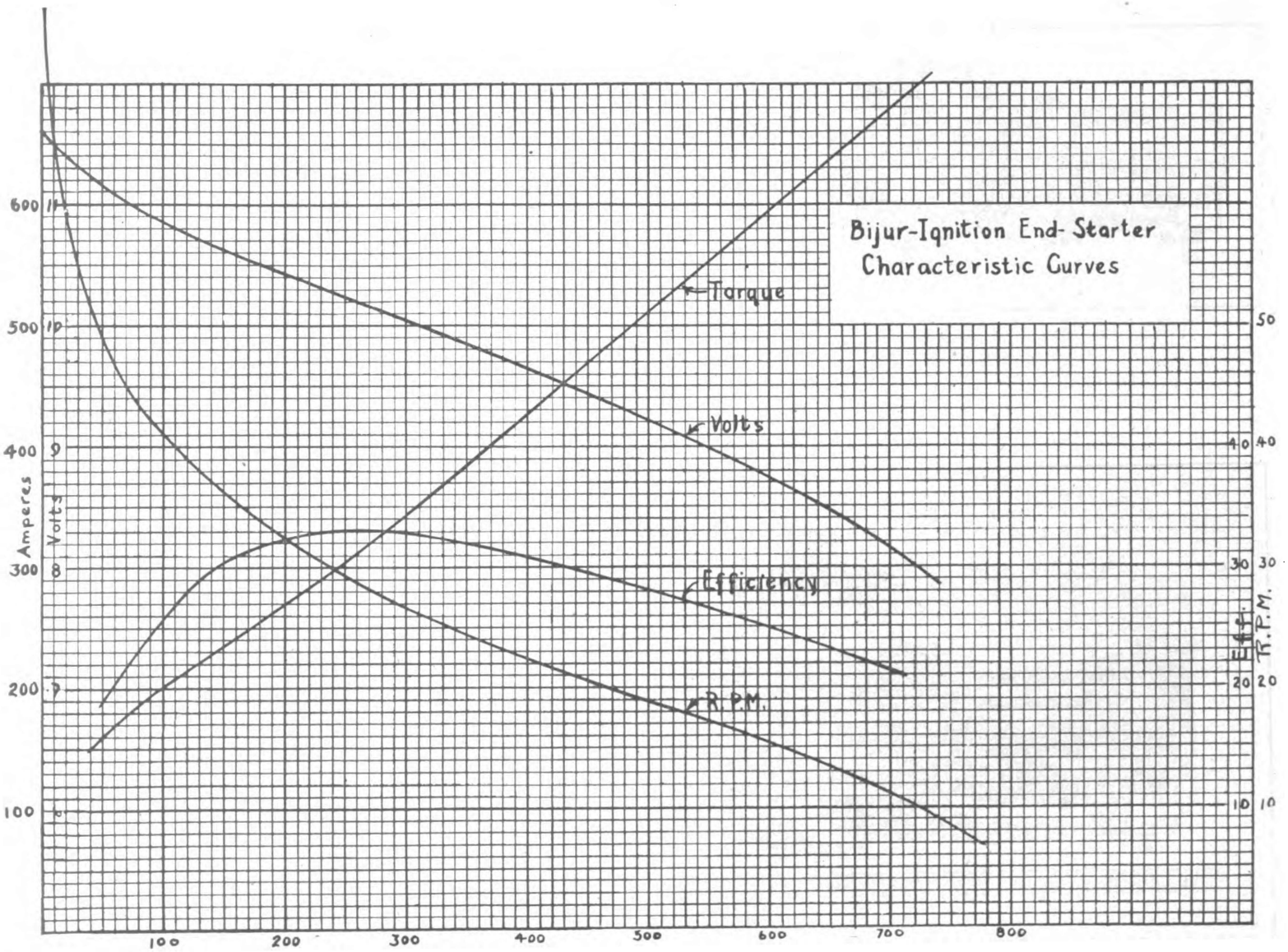

FIG. 4.

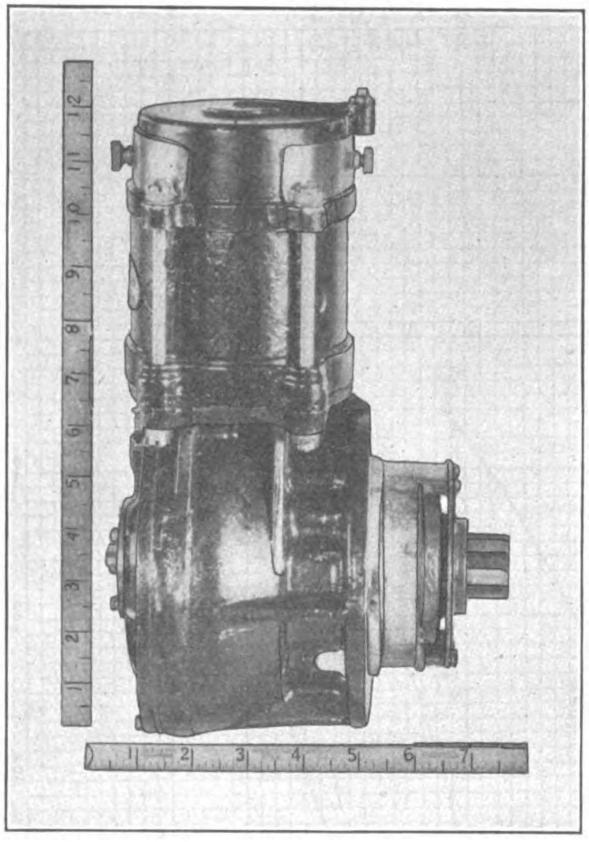

FIG. 5.—Bijur (rear end) starter, side view of assembly.

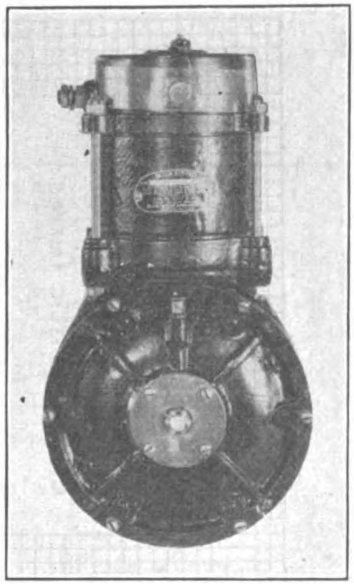

FIG. 6.—Bijur (rear end) starter, front view of assembly.

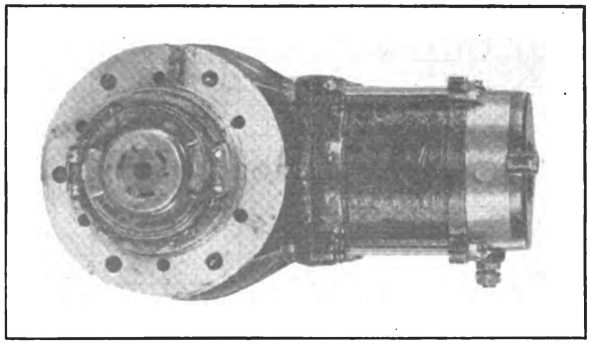

FIG. 7.—Bijur (rear end) starter, rear view of assembly

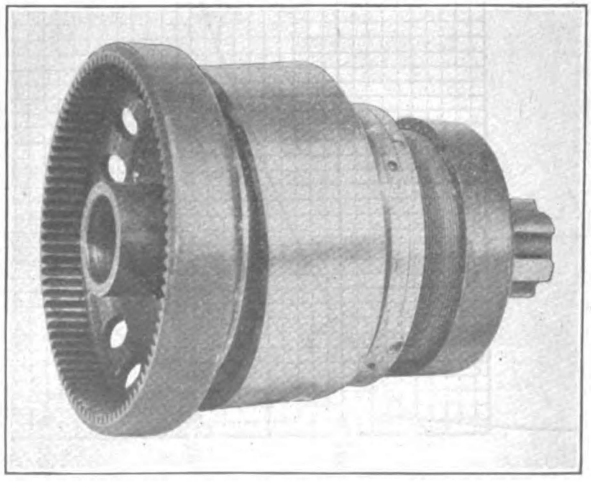

FIG. 8.—Bijur (rear end) starter driving barrel assembly, showing internal gear.

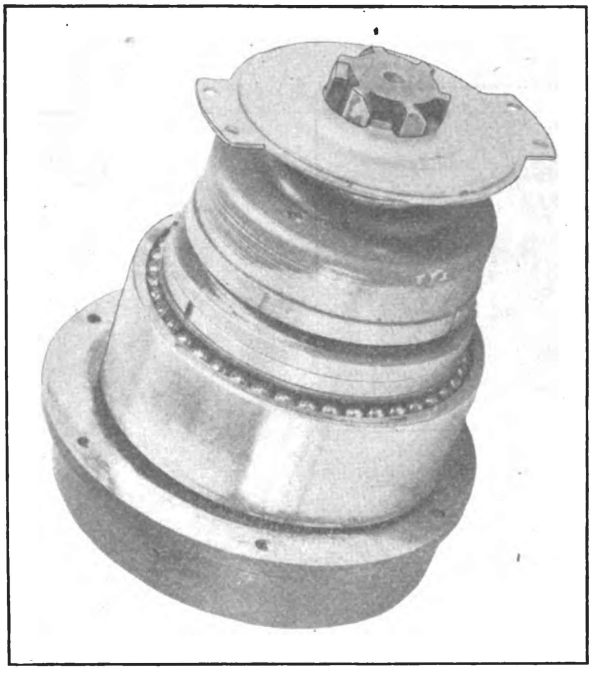

FIG. 9.—Bijur (rear end) starter driving barrel assembly mounted in roller bearing. Also friction discs.

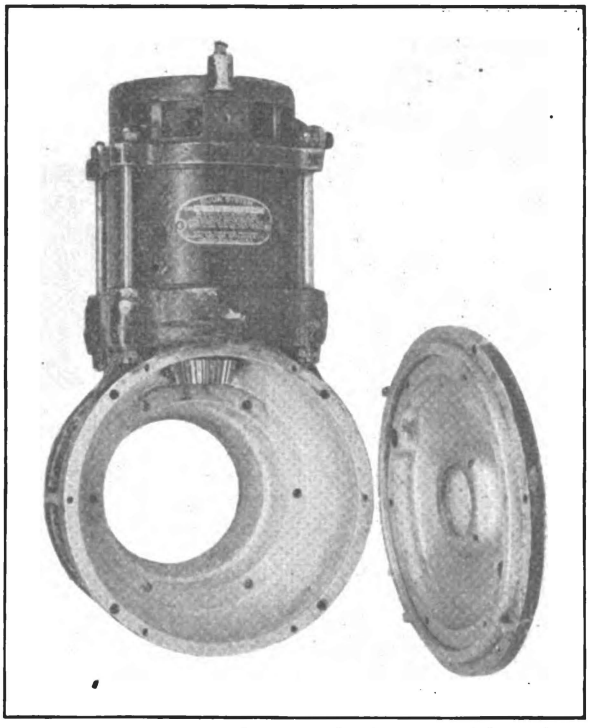

FIG. 10.—Bijur (rear end) starter, showing motor pinion and gear housing.

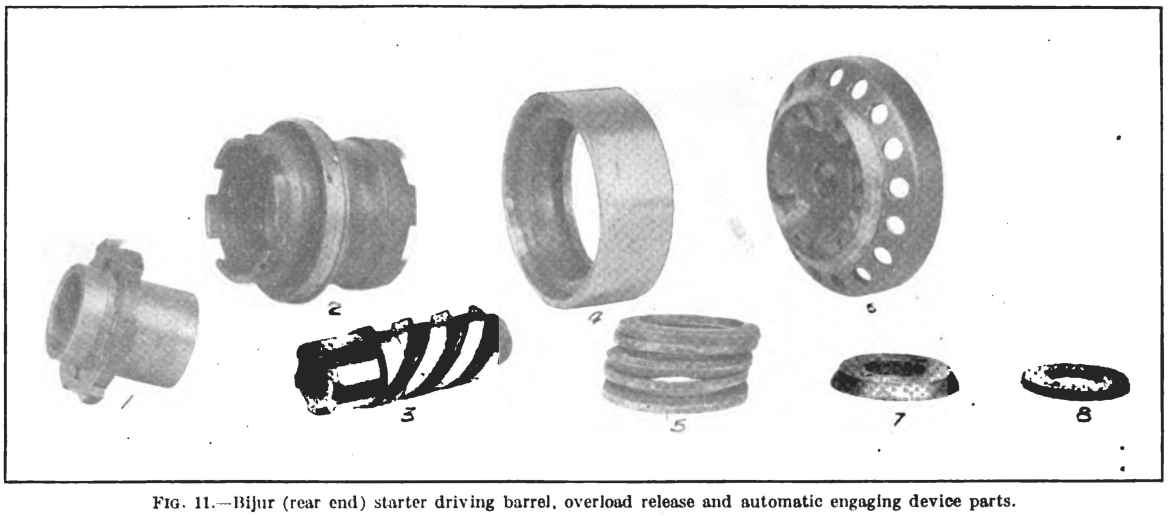

FIG. 11.—Bijur (rear end) starter driving barrel, overload release and automatic engaging device parts.

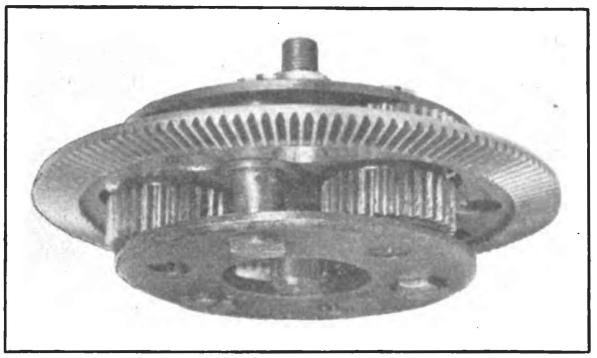

FIG. 12.—Bijur (rear end) starter bevel and idler gear assembly.

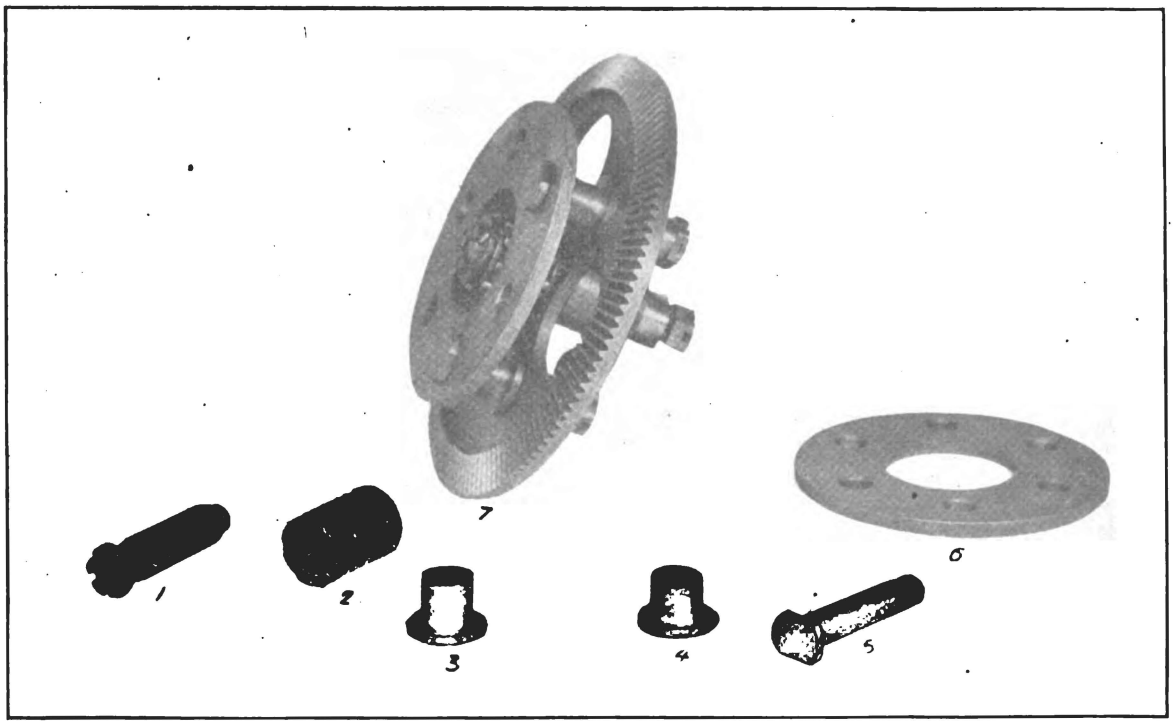

FIG. 13. -Bijur (rear end) starter, bevel and idler gear parts

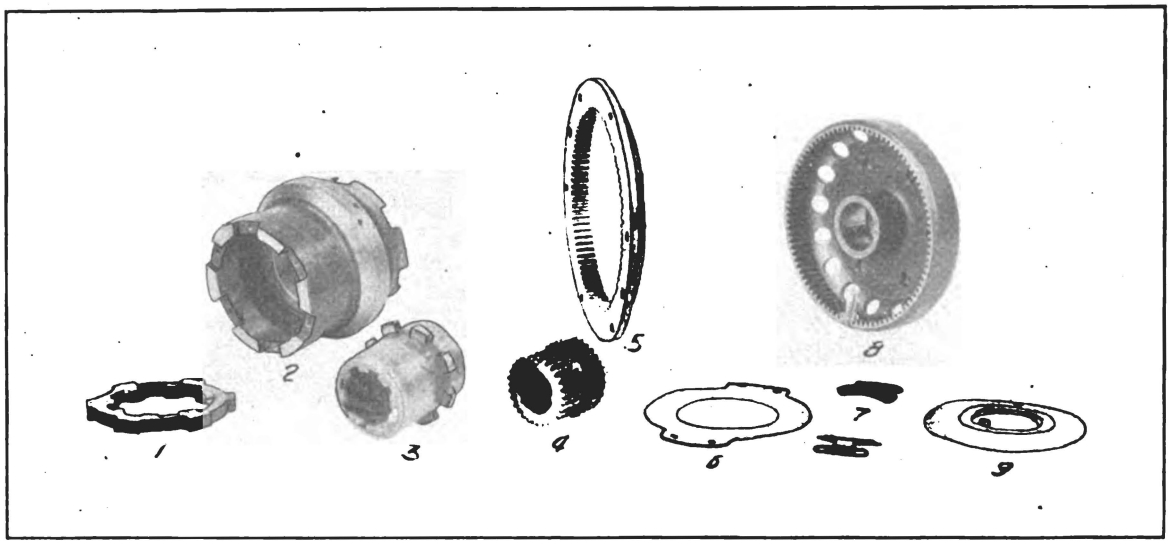

FIG. 14.—Bijur (rear end) starter parts.

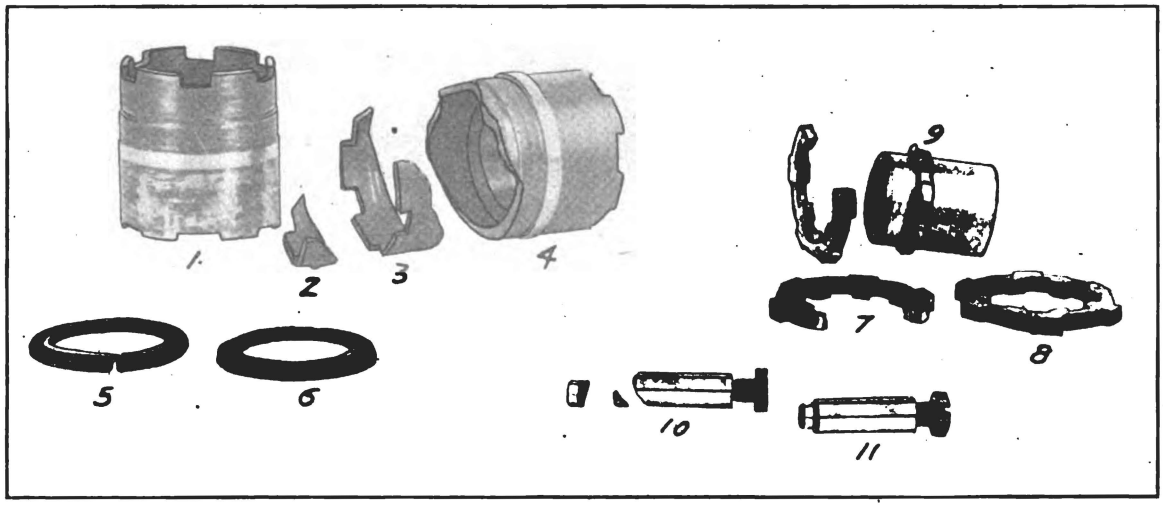

FIG. 15.—Bijur (rear end) starter, showing failure of several parts.

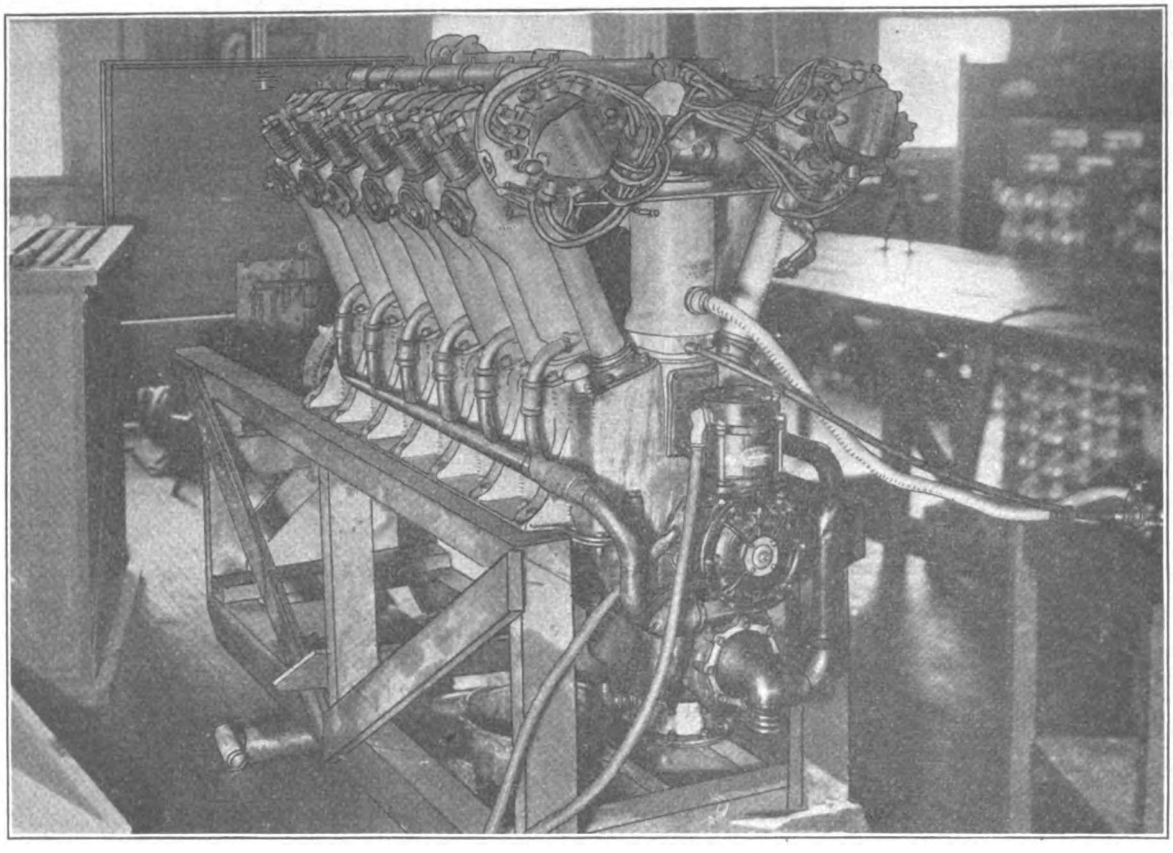

FIG. 16.—Bijur (rear end) starter installed.